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Current situation, trends and potential of renewable energy in Flanders

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ABSTRACT

The current European Union (EU) energy policy seeks to reach a balance between sustainable development, competitiveness and secure supply. In this sense, the EU energy policy sets the target of a 13% share of renewable energy sources (RESs) for Belgium. Several instruments have been implemented to reach this target. The objective of this study is analyzing those instruments and its effectiveness and efficiency. To tackle this objective, we first analyze the current status of RES in Flanders. Second, we compare the situation in Flanders to the national situation in Belgium and to the other EU member states. Then, we analyze the potential of each type of RES. Finally, we discuss the opportunities and problems of RES related to spatial planning. In Flanders, the main application of renewable energy is electricity production, of which the main source is biomass. An aspect of the Flemish energy policy worth mentioning is the green certificate system, which has stimulated the development of renewable energies. However, a greater effort to regulate this market and to decrease the cost of kWh produced has proven to be necessary. The RES-electricity share of total consumption has increased by 3.2% between 1994 and 2008. But, compared to others EU countries, the share of RES to gross inland consumption in Flanders is small. Large-scale facilities are necessary to reach the EU targets. The development of large wind, biomass and solar projects is suggested as the preferred option for Flanders.

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1. Introduction

The term ‘renewable energy source’ (RES), which is closely linked to sustainable development, is defined as any sustainable resource available in the long term in a simple long-lasting manner, found at a reasonable cost and applicable for any task without causing negative effects [1–3]. Several technologies are available for the production of clean, efficient and reliable energy from long-term RES, such as wind, sun, water, biomass and biogas, tides and waves, hydrogen and geothermal energy [3,4]. Also, it is further demonstrated that RES can increase the diversity of energy supply options in both developed and developing countries, and that doing so makes a strong contribution to the reduction of global and local air pollution [1,5]. Svensson et al. [6] point out that RES systems and nuclear energy have a low impact on climate change. Rodrigues et al. [7] believe that the increase in RES demand responds to the need of an increased share of carbon-neutral energy as an aid in the mitigation of climate change, and to the search of heightened energy independence.

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Table 1
Renewable energy inventory of Flanders (2005–2008).

Green electricity production (TJ) (net)	2005	2006	2007	2008
Hydropower	8.2	7.5	9.9	13.0
Wind energy	556.0	855.0	1,013.0	1,198.8
Solar (PV)	4.7	11.2	20.0	120.3
Waste incineration	574.3	749.5	922.0	961.6
Biomass	1,537.5	2,904.5	3,033.0	3,942.2
Biogas	800.7	624.2	907.5	954.4
Total green electricity	3,481.3	5,151.8	5,905.4	7,190.3
Gross electricity consumption (GEC)	210,327.8	216,441.1	217,430.6	215,960.9
Net green electricity/GEC (%)	1.7	2.4	2.7	3.3
Green heat production (TJ)	2005	2006	2007	2008
- by CHP plants[a]		2,153	3,074	3,252
- by plants that produce only heat		6,446	6,704	6,960
Total green heat production		8,598	9,777	10,213
Total heat		503,266	466,569	486,359
Green heat/total heat (%)		1.7	2.1	2.1
Biofuels consumption (TJ)	2005	2006	2007	2008
Biofuels for transport	0	0	1,996	2,179
Total road transport consumption	176,477	176,462	179,030	180,630
Biofuels/energy consumption in road transport (%)	0.0	0.0	1.1	1.2

[a] CHP units are defined as plants that produce electricity and heat, irrespective of the definitions of qualitative or non-quality CHP installations. *Source*: Jespers et al. [29].

Despite RES represent a huge energy potential, much larger than equivalent fossil resources, it is not their quantity which is the key limitation, but their nature, since they are usually diffused and not fully accessible, and some are even intermittent, and varies widely among regions [2,8]. Moreover, worldwide development of RES is currently limited by the high cost for development and implantation, uncertainty on local impact, insufficient funding for research and poor institutional and economic agreements, and limited availability of technological and economic know-how [9,10]. These problems can be solved by technical, economic, market, social and institutional means [2,10], but mainly through policies that incentivize and improve RES access to the power market [3,11]. According to Lund [12] and Omer [3] every responsible and sustainable energy policy must include the replacement of fossil fuels by RES, efficiency improvements in energy production, the rational use of energy in general and the reduction of energy consumption. EU energy policy is in agreement with the governmental policies implemented worldwide, as it incorporates energy efficiency, greenhouse gases reduction, renewable energies and energy savings in its work programmes for confronting a series of challenges, including perception of resource shortages, high cost of energy, security of energy supply and environmental protection [13,14].

The annual business volume of the RES market in the European Union (EU) is 15 million €, equivalent to half of the world market, in which the EU is a leading exporter [15]. Furthermore, the EU is the second largest power market in the world (450 million consumers), but the contribution of RES continues to be relatively small, only 6% in 2000 [16,17]. In this context, at the proposal of the Commission, the European Council approved the so-called 20-20-20 goals [18,19]. The RES goals are 20% of EU energy consumption from RES and an increase in the share of biofuels to 10% of the transport fuel mix consumed in the EU by 2020. The EU target set for Belgium is an RES share of 13% [20]. The Belgian National Action Plan, published in November 2010, does not establish a Flanders targets related to EU targets and the strategies to reach it in this sense.

The purpose of this study is to analyze the development of RES in Flanders and the instruments implemented to reach the EU RES target, and their effectiveness and efficiency. The analysis was done using available statistical data, and improved by interviews with a large number of people related to RES in Flanders.

2. Current situation of RES in Flanders

Solar water heaters, solar panels and wind turbines are becoming well established [21]. However, Flanders produces a lot more renewable energy from many lesser-known sources, such as biomass, biogas and even from waste. In the last years, the energy from wind and sun went through a larger development than the others types (Table 1). The use of solar energy to supplement daily electricity requirements, has such advantages as avoiding consuming resources and degrading the environment with polluting emissions, oil spills or toxic products [3].

In Flanders, the main application of RES is electricity generation, and two-thirds of this comes from biomass [22]. In 2008, Flanders consumed 33.5 PJ from biomass for energy purposes, 7.2 PJ (or 1.997 GWh) was the green energy produced, and 10.2 PJ the green heat ones. The total share of biomass in relation to the total gross inland energy consumption was 2.07% (Fig. 1). Since 2000, the share increased significantly in the transformation sector due to the green electricity and heat production. The transformation sector comprises the conversion of primary forms of energy to secondary and further transformation (e.g. coking coal to coke, crude oil to

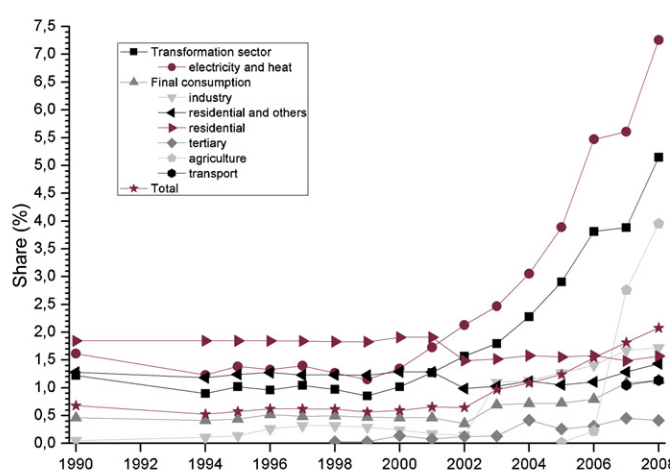

Fig. 1. Evolution of the share of biomass in relation to the total gross inland energy consumption by sectors in Flanders (1990–2008).

Table 2
Heat and power (CHP plants) in Flanders.

	Motors	Gas turbines	Combined cycle gas turbine (CCGT)	Steam turbines grid connected	Steam turbines with direct drive	Total
Electrical power (TJ)	1.1	1.7	3.1	0.6	0.5	6.9
Thermal power (TJ)	1.4	2.1	2.2	3.1	3.4	12.2
Elec. power quality–CHP (TJ)[a]	1.0	1.2	2.9	2.1	2.1	7.1
Electricity production (PJ)	3.6	7.9	20.5	2.1	3.6	34.2
Output production (PJ)						2.9
Hot water production (PJ)	4.7	11.8	13.0	13.7	23.3	5.4
Steam production (PJ)						61.1
Electrical efficiency (%)	37.8	34.5	45.6	11.3	11.0	29.4
Thermal efficiency (%)	49.4	51.6	28.8	72.6	72.2	51.7
Total efficiency (%)	87.3	86.1	74.4	84.0	83.2	81.1
Average full load time (ha^{-1})	3400	4630	6600	3730	7430	5450
CHP savings (PJ)	2.9	5.6	7.6	0.7	−3.3	13.4
Relative primary energy saving (%)	23	20	14	3	−11	9

[a] VREG data. *Source*: Cornelis et al. [23].

petroleum products, and heavy fuel oil to electricity). Related to the final consumption by all sectors together, the growing of the share of biomass energy was moderate in all the sectors (industrial, residential and agriculture). The transport sector experienced a higher increase since 2007 (estimated consumption data). In 2008, wood was the main biomass resource (55.73%) used in electricity and heat production.

The CHP production has experienced greater advances in the last years. In 2008, the electrical/mechanical power experienced the second largest increase in capacity in one year in the history of Flanders CHP (with 290 MW), and it represents an 18% increase in comparison to 2007 (Table 2). The increase is mainly situated in CHP with gas turbines (+141 MW, +42%), with motors (+99 MW, +50%) and steam turbines with direct drive (+41 MW, +42%). But, the share of RES and heat is marginal in the CHP production, and the main fuel is natural gas (67%). Over half of the primary energy savings realized in 2008 is characterized by a similar submission of CHP certificates [23]. Moreover, the CHP electricity produced from RES decreased by 17% in comparison to 2006 (820 TJ vs. 987 TJ). A similar trend (−40%) follows the renewable CHP heat (2143 TJ vs. 3560 TJ). Consequently, the share of renewable CHP energy to the useful energy CHP almost halved from 5.0% in 2006 to 2.8% in 2008.

A heavily dependence on local circumstances (local wind speed and turbulence) exists in Flanders. The areas with the best conditions to develop wind parks, in function of the average wind speed, are the western provinces of Flanders (West Flanders, East Flanders and Antwerp). Ghent and Antwerp port are suitable areas to install wind parks, due the less restrictions related to spatial planning. The energy generated by a wind turbine can be used directly or be delivered to the power grid. Most wind turbines have a total height of 150 m and 2–3 MWh of capacity. There are three kinds of wind turbines: small, medium and large-sized wind turbines. The small wind turbines are used to produce energy in a small scale (particular uses), and its expected return is rather limited.

The medium wind turbines provide a maximum power of 300 kW while the large-sized turbines produce more than 300 kW. The medium-sized wind turbines can make an important contribution to the public electricity production and transmission and can provide a solution where large-scale wind energy is not possible [21]. In 2009 a simplified authorization procedure for wind turbines in agricultural areas was approved. Before that, a special zoning plan was necessary, which needed a very time consuming procedure. The wind infrastructures can only be near industrial areas or highways.

For small-size wind turbines, the urban planning application must be submitted and reviewed by the municipality. The large and medium-scale wind turbines require the license for urban development (special application procedure to the Flemish regional government) and the environmental permit. The circular LNE/2009/01-RO/01/2009 [24] describes the framework for the assessment of license applications for the implantation of small and medium-sized wind turbines. The circular EME/2006/01-RO/2006/02 [25] describes the framework conditions for the implantation of medium and large-size scale wind turbines. According to this framework, large and medium-scale wind turbines need to be clustered within urban or industrial centres, port areas or larger scale infrastructures such as highways, railways, canals or high voltage electricity lines.

The Wind plan of the Flanders region provides the possible implantation sites for wind turbines and the average wind speeds. The selection of the possible implantation sites takes into account, among other, the following features: wind resource, location configurations, landscaping, connection to the grid, environmental conditions and bird protection areas. On the economic dimension, the plan provides an indication of the cost of the energy produced on the identified locations. The Flemish provinces of West Flanders (large-scale wind farms) and Oost-Vlaanderen (large, middle and small-scale wind turbines) have their own regulations, additional to the regional law.

The number of wind turbines installed in Flanders has increased approximately five fold during the period 1997–2007 (Fig. 2). The evolution has been uniform, and the electricity generated per

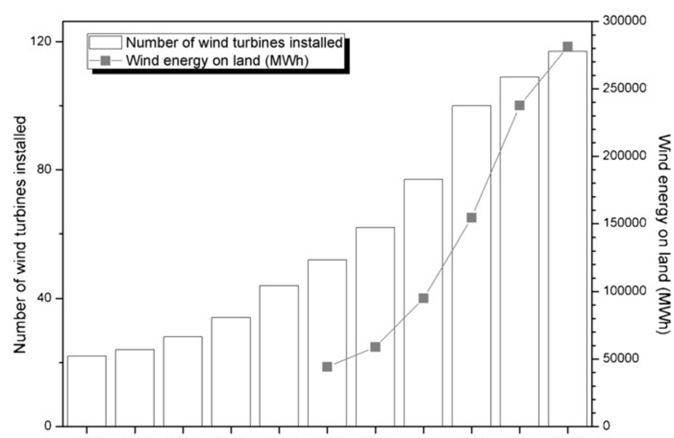

Fig. 2. Evolution of the number of wind turbines installed (1997–2007) and evolution of the production of green electricity from wind turbines.

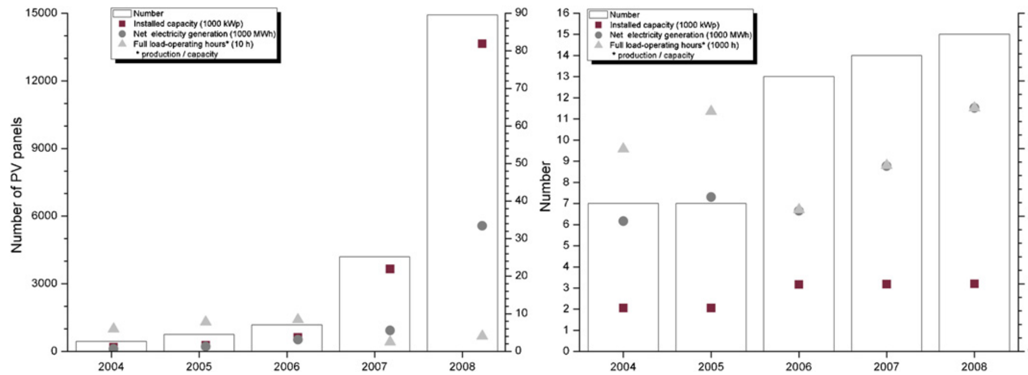

Fig. 3. Evolution of PV panels and hydro facilities in Flanders (2004–2008).

turbine increased from 0.36 GWh in 1997 to 2.41 GWh in 2007. In 2009, the 150 wind turbines located (registered) in Flanders produce 14% of the total green energy (387 GWh of 2688 GWh). It represents enough energy to supply more than 110,000 households [21]. The installation of off-shore wind turbines (on sea) is under the responsibility of the Federal Government. The industry has set itself the following objectives by 2020: 1500 MW in Flanders and 2800 MW in the North Sea. These are certainly achievable goals. In Flanders, this would mean that about 600 large-scale turbines are needed.

The study carried out by the International Energy Agency [26] determines that Belgium can reach 30% of its total electricity requirements from solar panels. Nowadays, only a small fraction of renewable energy in Flanders comes from solar energy (1.7% of electricity production in 2008) [23], despite its great potential (an average of 1000 h of sunshine per year) [21]. The installation of photovoltaic (PV) panels increased in recent years (Fig. 3), with a higher increment since 2006. In 2007, the net generation was small due the smaller amount of full load-operating hours of the panels. In 2009, 300 ha of solar panels are installed in the roofs in Flanders. The MWh per facility increased from 1.50 to 2.24 in the 2004–2008 period, and the maximum value was reached in 2006 (2.66).

From January 1, 2010, only PV systems installed on an insulated roof (in houses and buildings) are eligible for green certificates [27]. Nowadays, the solar systems for heat production are non-eligible for green certificates, despite its largest potential in Flanders. In 2009, solar water heaters were installed along 25,000 households, with approximately 10 ha of solar collectors on roofs.

In Flanders there are no waterfalls or big depressions, so large hydro-electric power stations are not built [21]. The main source of hydropower is by small-scale use (less than 10 kW) of limited natural decay of the water of rivers. Quite a few of the old water mills are into small hydro power stations. Since 2004, the number of hydro energy facilities multiplied by two times (Fig. 3), but the net generation of electricity only increased since 2007. The MWh per facility decreased from 275.14 to 240.00 in the 2004–2008 period, and the maximum value was reached in 2005 (326.14).

Hydro facilities can be found on channels and lock complexes, and they are hidden into the overall infrastructure of the complex. Examples are hydroelectric plants on the Zuidwillemsvaart in Bocholt en Lozen (Aspiravi sa, 60 and 100 kW, respectively), canal Leuven-Dyle (Enbo nv, 5 Kaplan turbines) and Albertkanaal in Wijnegem (nv De Scheepvaart, 125 kW) [28]. The green energy cooperative Ecopower cvba is developing small hydro facilities in Flanders. Some examples are the mills of Rotselaar (Francis turbine, 70 kW), Overijse (10 kW), Hoegaarden (Kaplan turbine, 30 kW), Schoonhoven (10 kW), Banmolens Harelbeke (Francis turbine, 30 kW), and KWC Sint Jorissluis (30 kW) that is in planning.

In 2007, the road transport consumed 2.2 PJ of bio-ethanol and biodiesel [29]. The use of renewable fuels (bio-oil, biogas, refinery gas and hydrogen) increased in the last years, reaching a 3% share [23]. Also, bio-ethanol was for first time available on the Belgian market in 2008. The Flemish Energy and Natural Resources Policy of 2004 and 2009 stipulated that by 2010, 25% of the electricity supplied in Flanders had to be generated by RES and cogeneration. Specifically, for renewable energy from wind, biomass and solar, the energy policy defines a 6% target of. The remaining 19% must be generated by cooling heating and power (CHP) plants [23]. The current government (2009–2014) decided to continue this policy until a new target for 2020 was drafted. Flanders finalized its Action Plan, and integrated it, and in consultation with the Federal Government, it was also integrated in the action plans of the other regions.

For the Flemish Government, biofuels are not a priority due to current problems with their production and their impact on agriculture, biodiversity, forests and land use changes. The Flemish Government is looking for other alternatives and new advances in the production of second and third generation biofuels.

2.1. Location of renewable energy facilities in Flanders

Wind turbines, especially large-scale, are usually located near urban or industrial centres, ports (Bruges, Gent and Antwerp) or larger-scale infrastructures such as highways and railways. Most wind turbines have been installed in the provinces of West Flanders, East Flanders and Antwerp. A map of potential areas for installation of future wind energy turbines in these provinces are shown in Fig. 4 (in brown). Note that not all wind turbines (in yellow) are currently installed in these potential areas.

Large-scale biomass facilities (in green in Fig. 4) are mainly located near ports (Gent and Antwerp), because most resources required for biomass energy production are imported from other countries, mainly from France. In Limburg, plentiful agricultural resources available led to the installation of small and medium-scale facilities.

2.2. Green electricity

The share of electricity from RES in total electricity consumption has increased to 3.3% in 1994–2008. Absolute values increased from 58 GWh to 1997 GWh by 2008. According to the Flemish Energy Agency [21], 2688 GWh of electricity were produced from green energy sources by 2009 (4.8% of total electricity consumption). In 1994, the electricity from waste incinerators was the main source (Fig. 5), but in the last five years, the majority of green electricity comes from biomass. Wind power was the second main source in

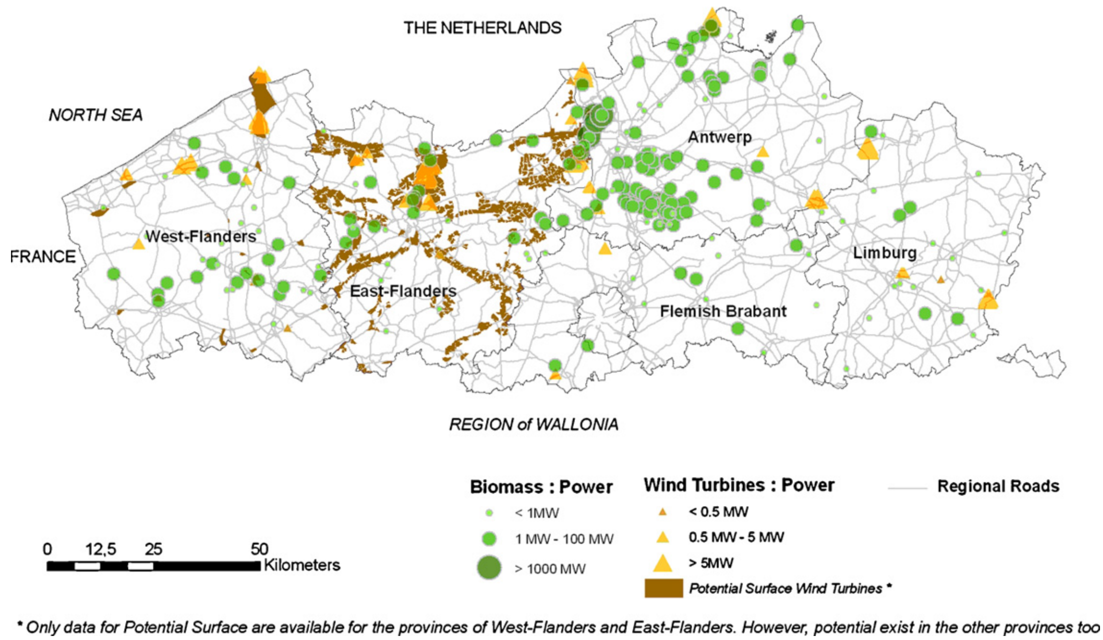

Fig. 4. Location of wind and biomass energy facilities in Flanders.

1994–2008. Although hydropower increased during this period, its share in the total electricity consumption has decreased.

In absolute terms, green electricity from biomass, wind, solar and hydro energy increased 1331 times during 2002–2008. Biomass has been responsible for over 80% of green electricity since 2004, especially the selectively collected waste biomass (Fig. 5). The largest increase was experienced by electricity from solar energy (6.7 times), but by 2008 it still only represented 1.7% of the total amount of green electricity. Wind energy, which provides almost 17% of the total green electricity production, increased by 750% in 2002–2008. In 2009, electricity from solar energy increased steeply to 138 GWh of the 2688 GWh total green power produced (5%) [21]. Almost 3 million m^2 of solar panels for electricity production were installed. Moreover, 100,000 m^2 of solar collectors for heat production supplied sanitary water heating for 25,000 Flemish families.

In 2006, the total primary CHP amounted to 4576 GWh [27]. Compared to the gross domestic electricity consumption (60,611 GWh), this represents a 3.3% share of net electricity

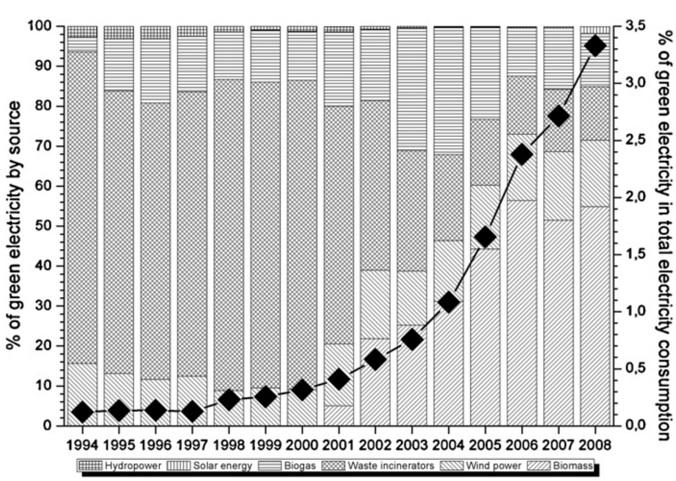

Fig. 5. Evolution of the share of green electricity in total electricity consumption, total and by source (1994–2008).

from renewable energy (1996 GWh) and 14.8% from cogeneration (8983 GWh). In 2007, 8983 GWh of electricity was produced in full or partial CHP plants. Of this total amount, according to Directive 2004/8/EC, 6187 GWh of electricity is considered as CHP. To be certified as qualitative cogeneration energy, the requirements are even stricter (related to primary energy savings), which results in an amount of 5242 GWh of qualitative cogeneration energy for 2007. The production of green heat in 2007 is estimated to be about 2716 GWh. This amount can divided based on origin, into biomass heating without CHP (1761 GWh), biomass heating and CHP (854 GWh), solar thermal (14 GWh) and heat pumps, heat pump water heaters and heat and cold storage or natural cooling (87 GWh).

2.3. Green certificate system

The Flemish region launched a Green certificate system (GCS) on 1 January 2002. There are two kinds of green energy certificates, compulsory and optional EUR [21]. From 1 January 2002, all electricity suppliers are required to sell a minimum amount of energy from renewable sources. Strong growth of Flemish RES electricity generation from 0.8% of electricity sales in 2002 to 4.9% in 2007 brought the 2010 6% target within reach [30]. A supplier can comply with this requirement by producing green energy himself or by buying green power certificates on the market. If an electricity supplier is not able to present the required amount of certificates, his licenses may be withdrawn or a penalty fee can be charged. The green energy certificates are granted to the free green power generators by VREG. The green power generators receive 1 certificate per 1000 kWh net of green electricity produced. They are allowed sell these certificates to the electricity suppliers.

The number of Green power certificates issued in 2002–2009 has increased almost 18 times (Table 3). According to technology, Biomass and Biogas have the largest number of green certificates. The sorted waste (collected selectively) is the main biomass resource to produce energy. The technology with the largest increase is PV, from five certificates in 2002 to 139,489 in 2009. This success is a consequence of high certificate prices in the first years of the system. The number of energy certificates decreased last year

Table 3
Evolution of the number of green power certificates issued for electricity produced from RES in Flanders (2002–2010).

	2002	2003	2004	2005	2006	2007	2008	2009	2010[a]	Total
Solar	5	82	393	715	1356	5582	33620	139489	133670	314912
Wind	44218	58946	95044	154446	237749	284520	332965	386851	166528	1761267
Water	1678	1863	1926	2283	2079	2733	3603	2971	1185	20321
Biomass 1	0	0	0	112443	395506	424321	661482	824072	243299	2661123
Biomass 2	0	0	52464	159505	180492	186602	179152	203543	86001	1047759
Biomass 3	54714	96729	184049	304481	424240	488698	526667	698176	177025	2954779
Biogas 1	37506	62191	74897	77050	81887	74926	74629	68177	25935	577198
Biogas 2	1501	1833	1965	2620	3472	4342	4723	5024	2681	28161
Biogas 3	10420	69924	135233	154746	101581	172820	193654	364601	93468	1296447
Total	150042	291568	545971	968289	1428362	1644544	2010495	2692904	929792	10661967

Biomass 1: from agriculture or forestry; Biomass 2: from household waste; Biomass 3: sorted waste collected selectively; Biogas 1: landfill gas; Biogas 2: WWTP; and Biogas 3: other.
[a] Until July, 2010.

due to their lower prices (2692,904 in 2009 and only 929,792 as of July 2010).

The GCS works better than traditional subsidies and is a relatively good option for developing renewable energies. The system achieved relatively good results right from the start, especially in promoting the installation of wind turbines and PV solar panels. However, the overall performance of the Flemish support system (effectiveness, efficiency and equity) is assessed as poor, despite its good short-term targets, costs and profits [30]. Moreover, there are no clear transition trajectories to a sustainable power system, and RES electricity generation from old waste-processing facilities is of dubious quality (effectiveness). Moreover, dynamic efficiency is spurious because there is no link to a technological industrial policy (efficiency). Finally, the polluter-pays principle is not respected, but jeopardized in the waste management sector (equity). These problems must be solved in the future, in order to achieve the EU energy policy targets and a real sustainable development.

Moreover, to avoid that the consumers pay for the increase of renewable energy consumption (by indirect tax for consumers) is necessary. In this sense, Verbruggen et al. [10] consider that the increasing internalization of externalities in the prices end-users face and by more focus on long-term interests are steps to reach the ideal economic potential of the renewable energies. Also, distributional impacts of the Green certificate system should be improved, because they are rather regressive. Currently, the incumbents reap most of the excess profits and not exist an equal spread of the burden over the electricity consumers due some discount for the largest customers [30].

This situation requires a large agreement between the government, the energy industry and the people. The market potential of renewables can be exploded by dedicated policies, implemented after a consensus, such as: changing in subsidies, levies and taxes to shift the prices experienced by market parties or reducing costs of RES options and helping in abolishing man-made barriers through technological innovations [10]. Also, policy makers need to get a better understanding of how investors behave, and of how they take their decisions (key psychological factors), to maximize the impact of future policies [31]. And, the social innovation induces changes in existing institutions by social networks, notably through collective actions [32].

The support for the development of renewable energy through the Green certification system, but changes are necessary to improve its results. Despite the Green certificates prices are among the highest in Europe, the associated policy effectiveness has been very low until 2008, and a rising trend appears since 2009 [30,33]. Verbruggen [30] believes that this system is a travestied premium support system and not a true certificates market. Also a better qualification is necessary, avoiding simplistic approaches and solutions that create biased systems and even derail other policy fields (in this case waste processing).

3. Flanders and EU RES indicators benchmarking

The variable availability of data makes it difficult to compare between the current situation of renewable energy in Flanders, the entire EU and its separate members states. However, in this section a valuable overview is given of the most relevant indicators, followed by a comparative discussion.

In 2008, the primary energy consumption (gross inland consumption + bunkers international) in Flanders reached 2044 PJ. Within this, the energy from biomass represented 1.6%. In relation to the gross domestic energy consumption (1613 PJ), the energy from biomass represented 2.1%. At EU member states level, Denmark, Sweden, Finland, Germany, the Netherlands and Austria made a great effort to reach their EU targets. Flanders had only a of 1.7% share of green electricity from RES in its total electricity consumption by 2005 (Fig. 6), and was still far from reaching the EU target (6.0%) for 2010. However, the whole country of Belgium had a 2.8% share by 2005, and if past performance have continued in 2005–2010, the EU target would be reached by 2010 (5.3% in 2008) (Fig. 6).

The relative share of RES-electricity in Flanders is half the relative share of all of Belgium. This means that the Walloon Region produces roughly three times more electricity from RES than Flanders. According to some experts interviewed in this study, this difference between the two regions is explained by the greater availability of biomass resources in the Walloon Region. Moreover, the relative Flemish share is only larger than the relative share of Estonia and Cyprus. In spite of this, the significant increase in its share from 0.21% in 2004 to 1.22% in 2007 highlights the effort made by the Flemish Government.

The share of RES to gross inland consumption in Flanders is small compared to the others EU countries (Table 4). Belgium, Netherlands, United Kingdom, Luxembourg and Malta had national shares fewer than 4% in 2008. Because the Belgium Renewable Energy Action Plan does not specify the target for the Flemish region, it is understood that Flanders should reach a 13% share of RES to gross inland consumption in 2020. Therefore, Flanders should make a greater effort to contribute achieve the Belgium target. The renewable energy per GDP of Flanders is only larger than that of the United Kingdom. The value of Belgium is more than two times the Flemish value, but still small compared to most other EU countries. Per capita, the value of Flanders is the smallest in comparison to EU countries.

Of the different RES, biomass is the largest in both Flanders and all of Belgium (Table 5). The share of biomass in Flemish RES production (82.3%) is the second largest in the EU after Hungary. The share of wind energy in Flanders is also relatively large (17.2%), and close to the EU27 shares (19.8%). Electricity production from other sources (hydropower, solar and geotechnical) makes up less than 1% and is relatively insignificant.

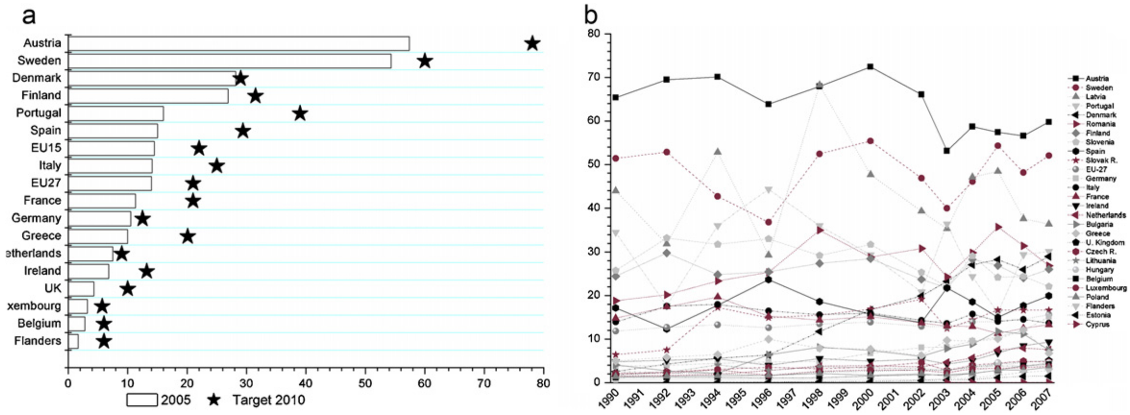

Fig. 6. 2010 EU electricity targets vs. 2005 green electricity production in Europe and Flanders (%) (a) and share of electricity generation from RES (%) to gross electricity consumption. Period 1990–2007 (b).

4. Opportunities and problems of RES related to spatial planning

In the Flemish region, the development of large-scale energy facilities is mainly limited by its high-density population and related factors, such as concentration of cities and infrastructures (roads, railroads, housing, factories, industrial areas, etc.). Other restricting factors are landscapes values, relief (mainly in hydropower facilities), monuments, natural protected areas, air-restricted areas, and so on. Finally, the aesthetics of renewable energy facilities is an important factor related to public acceptance. Many studies have examined the influence of the aesthetic aspect (or visual impact) of renewable energy facilities by use of photographs, interviews, surveys or computer simulations [34–37]. These methodologies are useful for the assessment of the visual impact of a single technology on a local scale (a single project) [7].

Table 4
Share of RES to gross inland consumption (%). Period 2005–2008.

	2005	2006	2007	2008	2020 target
Sweden	39.8	42.7	44.2	44.4	49
Finland	28.5	29.2	28.9	30.5	38
Latvia	32.6	31.3	29.7	29.9	40
Austria	23.3	24.8	26.6	28.5	34
Portugal	20.5	20.5	22.2	23.2	31
Romania	17.8	17.5	18.7	20.4	24
Estonia	18.0	16.1	17.1	19.1	25
Denmark	17.0	16.8	18.1	18.8	30
Lithuania	15.0	14.7	14.2	15.3	23
Slovenia	16.0	15.5	15.6	15.1	25
France	10.3	9.6	10.2	11.0	23
Spain	8.7	9.1	9.6	10.7	20
EU27	8.5	8.9	9.7	10.3	20
Bulgaria	9.4	9.3	9.1	9.4	16
Germany	5.8	7.0	9.1	9.1	18
Slovakia	6.7	6.2	7.4	8.4	14
Greece	6.9	7.2	8.1	8.0	18
Poland	7.2	7.4	7.4	7.9	15
Czech R.	6.1	6.4	7.3	7.2	13
Italy	5.2	5.3	5.2	6.8	17
Hungary	4.3	5.1	6.0	6.6	13
Cyprus	2.9	2.5	3.1	4.1	13
Ireland	3.1	3.0	3.4	3.8	16
Belgium	2.2	2.7	3.0	3.3	13
Netherlands	2.4	2.5	3.0	3.2	14
U. Kingdom	1.3	1.5	1.7	2.2	15
Luxembourg	0.9	0.9	2.0	2.1	11
Flanders	**0.2**	**0.9**	**1.1**	**1.2**	**13**[a]
Malta	0.0	0.1	0.2	0.2	10
Slovakia	6.7	6.2	7.4	8.4	14

[a] National target.

Table 5
Share of electricity from RES (%) to gross electricity generation, by type. 2007.

	Hydro	Wind	Biomass	Solar	Geothermal
EU27	59.0	19.8	19.4	0.7	1.1
Belgium	9.7	12.3	77.8	0.2	
Bulgaria	98.4	1.6			
Czech R.	61.1	3.7	35.2	0.1	
Denmark	0.3	64.8	34.9		
Germany	22.3	42.4	32.1	3.3	
Estonia	14.2	61.5	24.3		
Ireland	24.2	71.0	4.8		
Greece	56.4	39.6	4.0		
Spain	46.7	46.3	6.1	0.9	
France	86.0	5.9	8.1		
Italy	66.7	8.2	13.8	0.1	11.3
Cyprus				100.0	
Latvia	96.6	1.9	1.5		
Lithuania	72.5	18.2	9.3		
Flanders	0.2	17.2	82.3	0.3	
Luxembourg	36.3	21.7	34.9	7.1	
Hungary	10.4	5.4	84.2		
Netherlands	1.2	37.6	60.8	0.4	
Austria	86.0	4.8	9.2		
Poland	43.3	9.6	47.1		
Portugal	61.2	24.5	13.0	0.1	1.2
Romania	99.8		0.2		
Slovenia	96.7		3.3		
Slovak R.	89.8	0.2	10.0		
Finland	58.0	0.8	41.2		
Sweden	84.6	1.8	13.5		
U. Kingdom	25.0	25.9	49.0	0.1	

The "Projections on renewable energy and cogeneration to 2020" study [38] examined the potential of different technologies (electricity, heat and biofuels), and compared a business-as-usual scenario (BAU) with a pro-active policy (PRO). The Flemish Government used the calculated potential in the PRO scenario in its Energy Plan (Table 6).

In order to realize the potential of renewable energies in Flanders, the surface required for the installation of new facilities is

Table 6
Potential of renewable energies in Flanders.

Technology	2010 (GWh)	2020 (GWh)	Increase (%)
Wind onshore	521	1905	265
Wind offshore	320	3841	1100
Solar energy (PV)	174	935	437
Solar thermal	224	1193	433
Biomass plants for electricity production	97	217	124

calculated as follows. To reach the target of 1000 MW, 300 new 2.5-MW wind turbines (+750 MW) are necessary. Since the current legislation prescribes a minimum buffer distance of 250 m from any dwelling (radius = 250 m → area = 20 ha), a surface free of housing of 6000 ha is required. To reach the proposed 935 GWh by 2020, VITO assumes that the efficiency of solar panels will improve from the current 110 kWh m^{-2} per year to 170 kWh m^{-2} per year. Therefore, an additional 800 ha are necessary to install the required panels. An increase in surface of 300 ha for installing solar water heaters is desired by 2020. However, the installation of PV and thermal panels does not require the acquisition of new land, which makes it a good option. Currently there are 53 biogas plants in operation or under construction. According to the predictions of VITO, the number of these types of installations should be doubled by 2020.

The main environmental problems related to biomass and CHP facilities are the emissions of greenhouse gases (GHG) and the effect of noise and smell, in addition to the visual impact. Therefore, rural areas are the most suitable for the installation of biomass and CHP facilities. For such an installation, the availability of resources and connection to the power grid are essential. The cost price is usually not the limiting factor. Heat facilities have been observed to be the most used in the rural areas.

People commonly think that waste incineration (with a percentage of biomass) is considered as a way to produce renewable energy. However, to certificate it as a renewable source of energy production, the regulatory framework prescribes a required minimal percentage of biomass in the waste. Specific certificates exist for the energy produced from CHP installations. A Biomass CHP installation can obtain a CHP certificate and a Green certificate. Currently, the main challenges of this technology are to establish a reduction in GHG emissions, a reduction in size and a higher efficiency. Moreover, a more detailed regulation related to the use of biomass sources (especially pellets) is needed.

Wind turbines have been installed near large structures, such as industrial areas and highways, and near high power grids. The choice of such locations helps reduce the visual impact and the problem of the noise of wind energy turbines. Most past installation projects were medium or small scale (3–4 turbines) because of existing limitations (mainly the available surface). Nowadays, small wind turbines are considered inefficient. For the installation of any new wind energy turbine in Flanders, both a construction license and an environmental license are required. The entrepreneurs or private companies have to apply with the Flemish Government for these licenses. The main criteria for the installation of a new facility are a minimum distance of 250 m to the nearest house, and a maximum period of 30 h of effective shadow per year over on the nearest house. However, these criteria are not legally binding and are considered rather as guidelines than as regulations. Consequently, a stricter legislation is necessary to unambiguously define the criteria and parameters for the construction of wind. An important recent advance in this area is the development of an automated mechanism to stop the wind turbine when the maximum number of hours of effective shadow is reached.

The Wind plan for Flanders was launched in 2001. It includes potential areas for the installation of wind turbines according to their wind potential way, the provinces of West Flanders, East Flanders and Antwerp made a more advanced multiple-criteria map of potential areas for the installation of wind energy turbines (residential and industrial areas, protected landscapes, agricultural areas, recreational areas). However, these areas are only designated as suitable, and the map is not legally binding. The promoters can chose where they want to construct wind turbines (given they receive approval from the local administration).

The public opinion does not unanimously agree with the construction of new wind turbines, for reasons as visual contamination, pollution, and the generation of shadow or noise. Ek [39], Kaldellis [40] and Rodrigues et al. [7] consider the visual impact of large-scale facilities as a key parameter in the assessments of policy scenarios and in the development of future projects. Therefore, a more participatory approach for the development of renewable energy facilities is necessary Social networks can contribute in the emergence of wind power projects, as has been showing in several European countries where the innovating role of civil society for the implementation of wind power was applied [10,41,42]. Promoters must design new strategies and arguments to facilitate their installation. In addition, an improved distribution of revenues to the entire society is necessary. Nowadays, landowners and the entrepreneurs are the sole beneficiaries.

The Wind Energy working group is a good tool to perform a complete assessment of the installation of new wind turbines. This working group is composed by delegates of different areas of expertise: energy, infrastructure, nature and protected areas, tourism, etc. Its decisions are not mandatory, but reports are submitted to the decision makers (spatial planners), who decide on the installation new wind turbines. However, a more binding advice from the group should be required to enforce any technical criteria formulated by this group.

Most wind turbine facilities installed in Flanders do not have tourism potential since they are disseminated and commonly close to industrial areas or roads. Sometimes there are conflicts with existing monuments and historical cities for further tourism development. However, there is currently a site of wind turbines that is used for educational purposes in Ghent. Next to this, boat trips are organized to the offshore Wind Park near the Belgian coast (Thortonbank).

The installation of solar panels (at small and medium-scale) has seen a boom in the last year, mainly due to its promotion by the GCS and benefits for private promoters. PV panels are the most widespread. The installation of large-scale projects in Flanders (4–6 ha) is generally restricted by the limited availability of surface. The most suitable area for the installation of solar panels in Flanders is the North Sea coast (West Flanders Province). East of the Flemish region, the potential is reduced due to the proximity of higher lands and increased presence of clouds. Belgium is now the 6th most solar PV-intensive country in the world (defined by km^2 of solar panels). Price is the main limiting factor for installation of solar panels.

The cost price is the main limiting factor for the installation of solar panels. Currently an average investment of 20,000–25,000 € is required for the installation of 20 solar panels on a regular house roof. A restricting technical factor is the shadowing by nearby buildings. Around a 20% shadow on one solar panel suffices to stop the energy production of all the panels connected in the same loop.

The incorporation of infrastructure into buildings with heritage values and the reduction of main effects on the fauna and flora of the watercourse, specially the fish migration [28], are the main advances needed for the development of hydro facilities.

5. Conclusions: trends and future challenges of RES in Flanders

Several strategies to reach the EU RES target are established in the Belgium Renewable Energy Action Plan, according with the availability of resources and the potential of each one.

The electricity generation is currently the main application of renewable energies, while heat production (from heat pumps, wind, geothermal, solar) has the highest potential for further application and development in Flanders. In the research carried out by Möst and Fichtner [43], a substantial increase of renewable electricity use with high growth rates was forecasted when renewable energy sources for electricity generation targets or

incentive mechanisms are introduced. There are currently no concrete projects for developing geothermal energy. Should this be reconsidered, more effort by the regional government will be needed to develop this type of RES in the coming years.

The Flemish Government promotes RES through their green certificate pricing policy. First, wind facilities were promoted, followed by PV installations, and more recently biomass and CHP installations. With theses mechanisms, the Flemish Government strives to reach the EU 20/20/20 energy targets. However, a stronger effort to regulate the green energy market and to decrease the cost of kWh produced is necessary, because there are no clear transition trajectories to a sustainable power system. This situation requires broad agreement between the government, the power industry and the public. The RES market potential may be substantially increased by means of dedicated policies, implemented after consensus, such as, a better qualification system, different subsidies, levies and taxes to shift market prices, lowering the cost of RES, or helping abolish man-made barriers through technological innovation. But support for the development of RES through a modified or better GCS must continue in order to reach the EU targets and real sustainable development.

Benchmarking of relative Flanders and EU RES and RES-electricity consumption indicators shows that most of them are low. Despite this, increase in recent years has been significant and highlights the effort made by the Flemish Government.

Concerning spatial planning, the search for available suitable areas to install such facilities must be a priority for renewable energy policy makers. Ports, highways and industrial zones are priority areas for the installation of wind energy facilities. Verbruggen and Lauber [44] believe that "additional supplies on-top of own generated power should come where possible from local sources that can be developed, owned and operated by local companies". In addition, the specific potential and conditions of each individual region should be considered when setting regional prices for green certificates, and installation of renewable facilities in areas with lower potential should be promoted (e.g. wind energy in Brabant-Flanders and Limburg). These measures would help decentralise energy production, bring production closer to consumers and avoid grid losses from long-distance energy transport.

The large increase in PV solar energy production is accompanied by problems between producers and distribution companies, and further regulation is required in this field. In addition, a better distribution grid is needed, since the current grid is not well adapted to receive all the renewable energy produced.

Finally, better regulatory framework co-ordination between governmental departments and the energy is required for the EU, Belgian and Flemish targets to be met.

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